NON-LINEAR OPTIMIZATION USING CLASSICAL & EVOLUTIONARY ALGORITHM FOR RADAR DETECTION OF TARGETS

Thesis submitted in partial fulfillment of the requirements for the degree

of

Bachelor of Technology

in

Electronics and Communication Engineering

By
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Department of Electronics & Communication Engineering
National Institute of Technology
Rourkela

2010-2014

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Under the guidance of
Prof. Subrata Maiti

Department of Electronics & Communication Engineering
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Dedicated to My Parents

National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled, "**NON-LINEAR OPTIMIZATION USING CLASSICAL & EVOLUTIONARY ALGORITHM FOR RADAR DETECTION OF TARGETS**" submitted by **Nishant Das(110EC0237)** for the award of **Bachelor Of Technology** degree in **Electronics and Communication Engineering** during session 2010-2014 at National Institute of Technology, Rourkela is under my supervision and guidance.

Date : **Prof. Subrata Maiti**

Place : Rourkela Dept. of Electronics & Communication Engineering

National Institute of Technology, Rourkela

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CONTENTS

Abstract ……………………………………………………………………………..09

1. Chapter 1

Ground Penetrating Radar …………………………………………………………10

1.1 Introduction ……………………………………………………………..10
1.1.1 A Brief Idea on Radar ……………………………………………..11
1.2 What is GPR? ……………………………………………………………..12
1.3 Basic Principles …………………………………………………………..13
1.4 How does GPR work? …………………………………………………15

2. Chapter 2

Modeling of GPR system ………………………………………………………..20

2.1 Electric and Magnetic properties of medium ……………………21
2.1.1 Permittivity-ε …………………………………………………………….21
2.1.2 Conductivity-σ …………………………………………………………...21
2.1.3 Permeability-μ …………………………………………………………...22
2.2 Forward Modeling ………………………………………………………..22
2.2.1 Reflection Coefficient ……………………………………………….22
2.2.2 Global Reflection Coefficient ……………………………………23
2.3 Synthetic Modeling of GPR system …………………………………25
2.4 Non-linear optimization techniques used in study of GPR ……..27
2.4.1 Steepest Descent Method ………………………………………….28
2.4.2 Conjugate Gradient Method ………………………………………..29
2.4.3 Minimization using Simplex Method ………………………….30
2.4.4 Minimization using Steepest Descent Method ………………..30
2.5 Objective function of the GPR modeling system ………………31

3. Chapter 3

Applications and Challenges ………………………………………………32

3.1 GPR Applications ……………………………………………………33

3.1.1 Advantages of GPR system ……………………………………….34
3.1.2 Drawbacks ………………………………………………………...34
3.2 Technical Challenges in GPR ……………………………………...34

4. Chapter 4

Summary and Conclusion ………………………………………………….37

References ………………………………………………………………….38

LIST OF FIGURES

Figure 1.1 a) refraction of wave along a ray-path of the wave front (b) refraction of a wave at the critical angle of incidence. ……………………………………………………14

Figure 1.2 The process of constructing a scan from a series of traces measured along the surface. Sequence of producing a GPR profile: 1. transmit and receive electromagnetic energy, 2. the received energy is recorded as a trace at a point on the surface, 3. traces are arranged side-byside to produce a cross section of the earth recorded as the antennas are pulled along the surface. Traces are displayed as either wiggle trace, or scan plots (gray scale or color assigned to specific amplitudes). ……17

Figure 1.3 Scattering mechanisms: (a) specular reflection scattering, (b) refraction scattering, (c) diffraction scattering, and (d) resonant scattering. ……………………..18

Figure 2.1 A two-layer ground subsurface with the transient response analysis …….22

Figure 2.2 An L-layered ground subsurface with the corresponding electric and magnetic properties. ………………………………………………………………………….23

Figure 2.3 A simple mono media ground surface. ……………………………………..24

Figure 2.4 The MATLAB plot for the transmit and the received signal from a ground surface. ……………………………………………………………………………………24

Figure 2.5 A three-layered media with different electric and magnetic properties. …25

Figure 2.6 Modelled reflection coefficient Amplitude spectrum. ……………………..26

Figure 2.7 Modelled reflection coefficient Phase spectrum. ……………………………27

Figure 2.8 Algorithm for the Steepest Descent Method. …………………………………..28

Figure 2.9 Algorithm for the Conjugate Gradient Method. ……………………………29

Figure 2.10 Plot for the function $f(x_1,x_2)$ using Simplex Method. ………………………30

Figure 2.11 Plot for the function $f(x_1,x_2)$ using Steepest Descent Method. ……………30

ABSTRACT

The main objective of this project is to study about the basics of Ground penetrating Radar (GPR) and optimize various multi-variable non-linear functions using the non-linear techniques such as Conjugate Gradient method, Steepest Descent Method.

Ground penetrating radar (additionally alluded to as GPR, ground probing radar, or georadar) is a close-surface geophysical device with an extensive variety of requisitions. In the course of recent years, GPR has been utilized effectively to help within compelling issues in various fields, for example, archaeology, environmental site characterization, glaciology, hydrology, land mine/unexploded law identification, sedimentology, and structural topography. By and large, nonetheless, GPR reviews have been arranged or executed with next to zero understanding of the physical premise by which GPR works and is compelled. The objectives of this preparation are to (1) give a prologue to the essential variables related to GPR and (2) to clarify the pertinent parts of these variables in GPR securing, trying to give key information to enhancing GPR use later on.

1. Chapter 1

GPR (Ground Penetrating Radar)

1.1 INTRODUCTION

1.1.1 A BRIEF IDEA ON RADAR:-

Radar is an object detection system which uses radio waves to determine

- Range
- Altitude
- Direction
- Speed of objects

Used in detection of

- Aircraft
- Ships
- Spacecraft
- Motor vehicles
- Weather formations

Radar Equation

The power P_r returning to the receiving antenna is given by the equation :-

$$P_r = (P_t G_t A_r \sigma F^4) / ((4\pi)^2 R_t^2 R_r^2)$$

Where,

P_t = Transmitter Power

G_t = Gain of the Transmitting Antenna

A_r = Effective aperture of receiving antenna

σ = Radar cross-section of target

F = Pattern propagation Factor

R_t = Distance from Tx to the target

R_r = Distance from target to the Rx

1.2 WHAT IS GPR?

Ground penetrating radar (called as GPR) is a high resolution electromagnetic system which is composed principally to examine the shallow subsurface of the earth, building materials, and roads and scaffolds. GPR has been created in the course of recent years for shallow, high determination examinations of the subsurface. GPR is a period-subordinate geophysical method that can give a 3-D pseudo picture of the subsurface, including the fourth measurement of color, and can likewise give accurate depth estimates to numerous normal subsurface items. Under good conditions, GPR can give exact data concerning the way of covered articles. It has likewise turned out to be a device that might be worked in boreholes to expand the extent of examinations far from the boundary of the hole.

GPR utilizes the principle of scattering of electromagnetic waves to find buried objects. The essential standards and hypothesis of operation for GPR have developed through the orders of electrical engineering and seismic investigation, and professionals of GPR have a tendency to have foundations either in geophysical investigation or electrical engineering. The central rule of operation is the same as that used to locate air ship overhead, yet with GPR that radio wires are moved over the surface as opposed to turning around a settled point. This has prompted the requisition of field operational standards that are undifferentiated from the seismic reflection system.

GPR is a method that is normally utilized for natural, designing, archeological, also other shallow examinations. The principal standards that are portrayed in the accompanying content apply to these provisions.

1.3 BASIC PRINCIPLES:-

The useful result of the radiation of electromagnetic waves into the subsurface for GPR estimations is indicated by the fundamental working standard that is illustrated in Figure A1. The electromagnetic wave is transmitted from a transmitting antenna, goes through the material at a speed which is resolved principally by the permittivity of the material. The wave spreads out and ventures descending until it hits an object that has distinctive electrical properties from the encompassing medium, is scattered from the object, and is detected by a receiving antenna. The surface encompassing the propelling wave is known as a wavefront. A straight line attracted from the transmitter to the edge of the wavefront is known as a ray. In the event that the wave hits a covered object, then some piece of the waves energy is "reflected" over to the surface, while some piece of its energy keeps on travelling descending. The wave that is reflected once more to the surface is caught by a receiving antenna, and recorded on an digital storage device for later interpretation.

Antenna apparatuses might be recognized to be transducers that change over electric currents and flows on the metallic radio wire components to transmit electromagnetic waves that spread into a material. Antennas transmit electromagnetic vitality when there is a change in the speeding up of the present on the recieving wire. The speeding up that causes radiation may be either linear,(e.g., a period-shifting electromagnetic wave going on the antenna), or precise increasing speed. Radiation happens along a curved path, and radiation happens whenever that the current alters course (e.g. at the end of the antenna element). Controlling and coordinating the radiation from an antenna is the motivation behind antenna design.

Antennas also convert electromagnetic waves to currents on an antenna element, acting as a receiver of the electromagnetic radiation by capturing part of the electromagnetic wave. The *principle of reciprocity* says that the transmit and receive antennas are interchangeable, and this theory is valid for antennas that are transmitting and receiving signals in the air, well above the surface of the ground.

Electromagnetic waves travel at a specific velocity that is determined primarily by the permittivity of the material. The relationship between the velocity of the wave and material properties is the fundamental basis for using GPR to investigate the subsurface. To state this fundamental physical principle in a different way: the velocity is different between materials with different electrical properties, and a signal passed through two materials with different electrical properties over the same distance will arrive at different times.

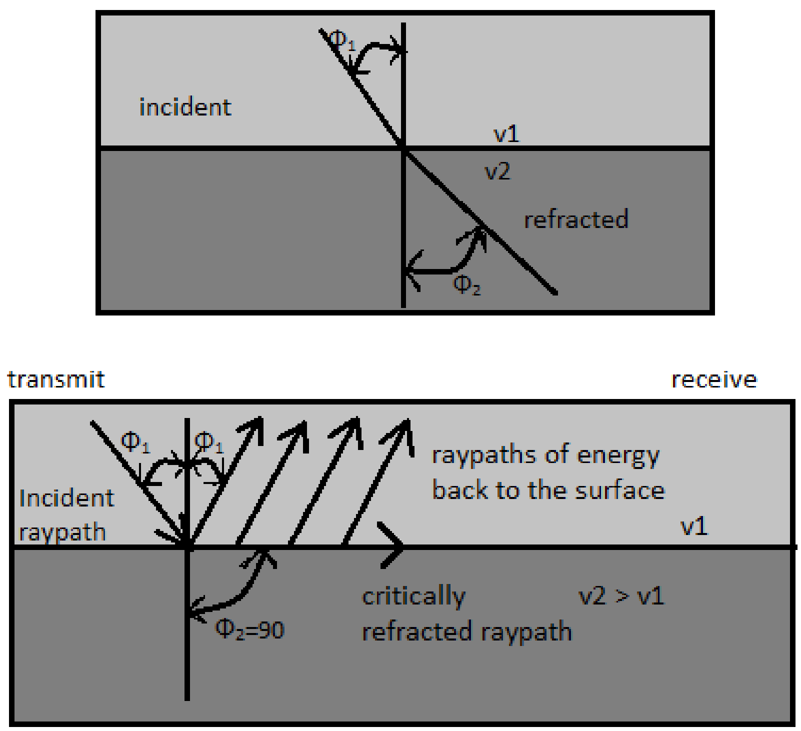

FIGURE 1.1. (a) refraction of wave along a ray-path of the wave front

(b) refraction of a wave at the critical angle of incidence [3]

The interval of time that it takes for the wave to travel from the transmit antenna to the receive antenna is simply called the *travel time*. The basic unit of electromagnetic wave travel time is the nanosecond (ns), where 1 ns = 10-9 s.

the velocity of an electromagnetic wave in air is 3x108 m/s (0.3 m/ns), then the travel time for an electromagnetic wave in air is approximately 3.3333 ns per m traveled. The velocity is proportional to the inverse square root of the permittivity of the material, and since the permittivity of earth materials is always greater than the permittivity of the air, the travel time of a wave in a material other than air is always greater than 3.3333 ns/m.

1.4 HOW DOES GPR WORK?

Acknowledging the wave scattered from the object in Figure A1, if a receive antenna is exchanged-on at absolutely the moment that the beat is transmitted, then two beats will be recorded by the receive antenna.

The primary beat will be the wave that ventures straight forwardly through the air (since the speed of air is more terrific than any viable material), and the second beat that is recorded will be the beat that goes through the material and is scattered again to the surface, going at a speed that is dictated by the permittivity (e) of the material. The ensuing record that is measured at the receiving antenna is like one of the time-adequacy plots , with the "input" wave comprising of the immediate wave that goes through air, and the "output" beat comprising of the wave reflected from the covered dissipating body.

The recording of both beats over a time of time with receive antenna system is known as a "trace", which might be considered a period-history of the go of a solitary beat from the transmit antenna to the receive antenna, and incorporates every last bit of its diverse travel ways. The trace is the essential estimation for record-breaking-space GPR studies. A scan is a follow where a color scale has been connected to the adequacy values. The round-outing (or two-way) travel time is more amazing for profound articles than for shallow items.

Thusly, the time of landing for the reflected wave recorded each one follow might be utilized to focus the profundity of the covered article, if the speed of the wave in the subsurface is known. The standards of building an output from a scan of traces is demonstrated .

The trace is the time-history record (measured in nanoseconds for radar waves) of a tiny piece (in the spatial sense) of a pulse of electromagnetic energy that travels from the transmit antenna and ends up at the receive antenna. If a portion of the wavefront encounters an object with a permittivity different from the surrounding material (host media), then that portion changes direction by a process that is called scattering. Scattering at the interface between an object and the host material is of four main types: 1) specular reflection scattering, 2) diffraction scattering, 3) resonant scattering, and 4) refraction scattering.

If the transmit and receive GPR antennas separate entities, then the system is called a *bistatic* antenna arrangement. If bistatic GPR antennas are deployed with the transmit and receive antennas located closely together, then the energy that is recorded is often called *back scattered* energy. If the same antenna is used for transmitting and receiving the signal, then the antenna system is called a *monostatic* system. Specular scattering is based on the Law of Reflection, where the angle of reflection is equal to the angle of incidence, or $\phi_1 = \phi_2$.

When a wave impinges on interface, it scatters the energy according to the shape and roughness of the interface and the contrast of electrical properties between the host material and the object. Part of the energy is scattered back into the host material, while the other portion of the energy may travel into the object. The angle that the wave enters into the object is determined by Snell's law, which can be stated as follows:

$$V_1/V_2 = \sin\phi_1/\sin\phi_2$$

where v1 and v2 are the velocities of the wave through the upper and lower materials, respectively, and f1 and f2 are the angles of the ray path for the incident and refracted waves, respectively.

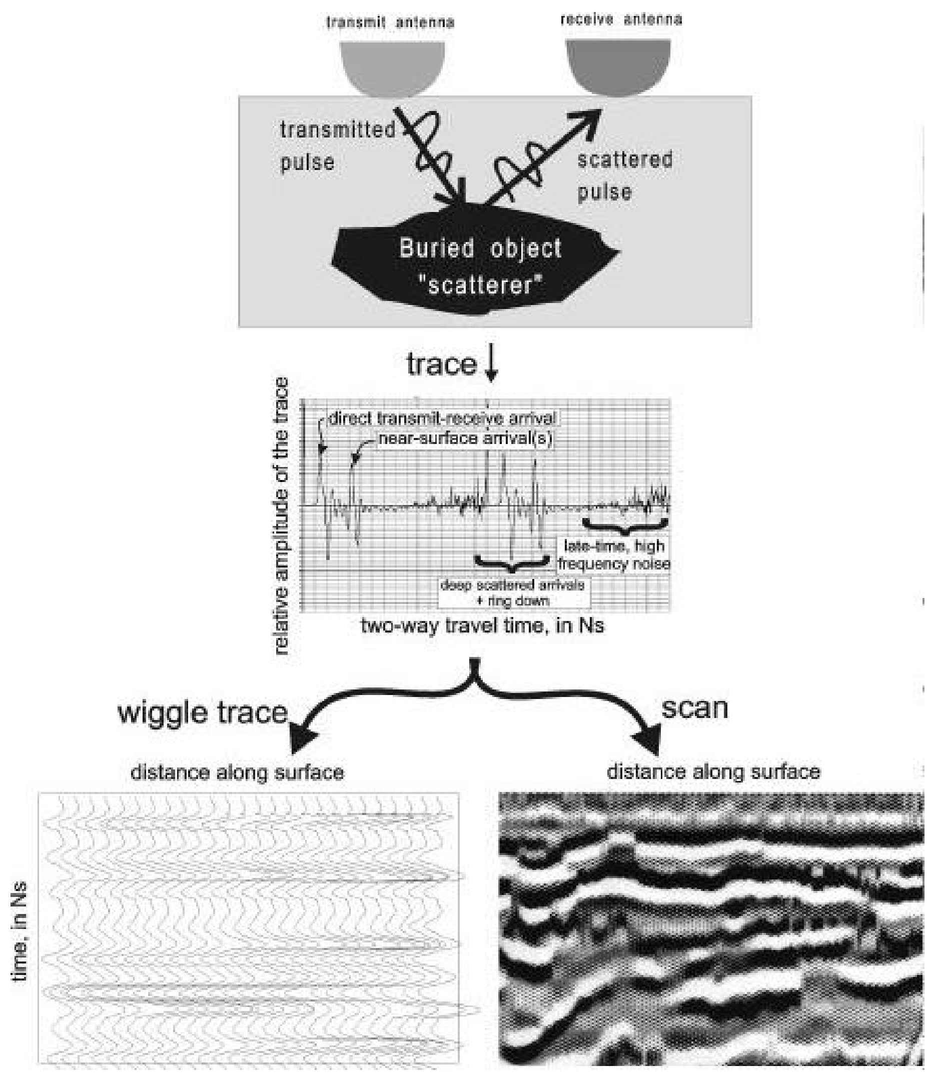

FIGURE 1.2. The process of constructing a scan from a series of traces measured along the surface. Sequence of producing a GPR profile: 1. transmit and receive electromagnetic energy, 2. the received energy is recorded as a trace at a point on the surface, 3. traces are arranged side-byside to produce a cross section of the earth recorded as the antennas are pulled along the surface. Traces are displayed as either wiggle trace, or scan plots (gray scale or color assigned to specific amplitudes).[3]

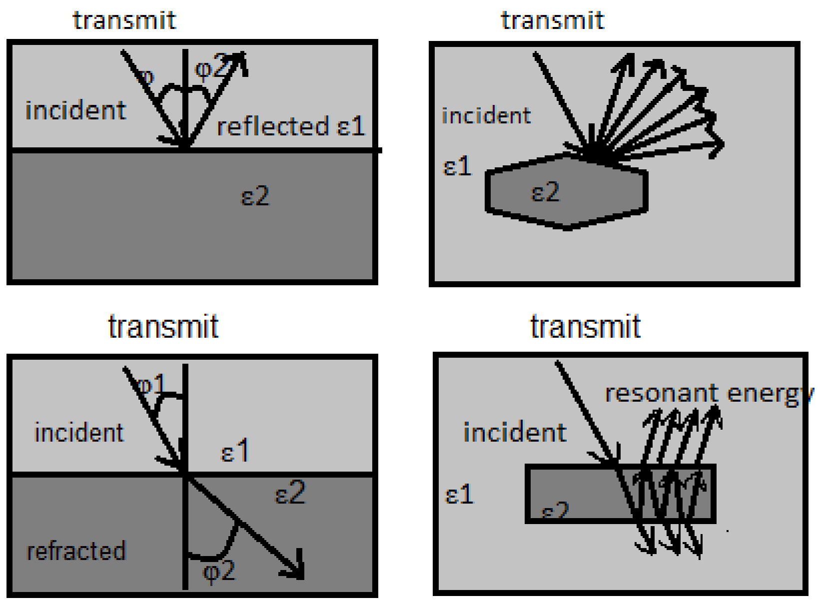

FIGURE 1.3. Scattering mechanisms: (a) specular reflection scattering, (b) refraction scattering, (c) diffraction scattering, and (d) resonant scattering. [3]

If the interface is smooth and continuous (e.g., a layer boundary), and velocity of the wave in the lower boundary (e.g., the object, or lower layer) is greater than velocity in the host material, then the wave within the object we'll travel along the interface with a velocity that is equal to velocity of wave in the object. The angle where this occurs is called critical angle, and can be determined by the following equation:

$$\sqrt{\varepsilon_2}/\sqrt{\varepsilon_1} = V_1/V_2 = \sin\phi_1$$

The distance that the receiver must be from the transmitter to receive a refracted wave is called the critical distance. Refracted waves are uncommon as a propagation path for GPR, since the electromagnetic wave velocity tends to decrease with depth. This is a consequence of the fact that seismic and electromagnetic wave velocities in partially saturated and unconsolidated materials are affected primarily by the water content.

Diffraction (Figure A4-c) is the bending of electromagnetic waves. Diffraction scattering occurs when a wave is partially blocked by a sharp boundary. Huygen's Principle of spherical spreading applies, but since the wave scatters off of a point, the wave spreads out in different directions, as first noted by Fresnel (1788-1827). The nature of the diffracted energy depends upon the sharpness of the boundaries and the shape of object relative to the wavelength of the incident wave. Diffractions commonly can be seen on

GPR information as semi-reasonable vitality designs that spread out in a few bearings from a point, or an along a line. Topographically, they frequently are measured in the region of a vertical flaw, or a brokenness in a geologic layer (unexpected facies change).

Thunderous scrambling happens when a wave encroaches on a shut item (e.g., a chamber), and the wave skips here and there and then here again-between distinctive purposes of the limit of the article. Each time the wave hits a limit, some piece of the vitality is refracted go into the host material, and a piece of the vitality is reflected go into the article. This causes the electromagnetic vitality to reverberate (off and on again called ringing) inside the article. The resounding vitality that is trapped within the item rapidly scatters as a component of it is re-emanated to the outside of the article. Shut articles are said to have a full recurrence that is focused around the span of the item, and the electrical properties of the article and the encompassing material. In any case, the capability of an article to resound relies on upon the wavelength (speed of the item, separated by the recurrence of the wave) concerning measurements of the item. The time span that an item reverberates is controlled by the permittivity differentiate between the article and the encompassing material.

In practice, GPR estimations might be made by towing the reception apparatuses persistently over the ground, or at careful focuses along the surface. These two modes of operation are shown in Figure A5. The altered-mode radio wire plan comprises of moving reception apparatuses freely to diverse focuses and making prudent estimations, while moving-mode keeps the transmit and accept recieving wires at a settled separation with the recieving wire pair moved along the surface by pulling them by hand, or with a vehicle. The altered-mode course of action has the focal point of adaptability, moving-mode has the preference of quick information securing. In practice, a synthesis of altered-mode and moving-mode gives an ideal mixture of adaptability and portability. Estimations made in the settled mode could be utilized to focus the best dispersing and recieving wire introduction for making moving mode estimations. A few frameworks empower the driver to make both sorts of estimations with the same recieving wires and gadgets.

2. Chapter 2
Modeling of GPR System

2. Modeling of GPR System

2.1 Electric and Magnetic properties of medium

2.1.1Permittivity – ε

It speaks to the capacity of a material to store and discharge EM wave vitality as static electric charge particles. It can likewise be portrays as the capacity of material medium to confine the stream of charge transporter through it as EM wave or the degree of polarization that medium experiences because of electric field segment of EM wave going through it . Subsequently EM wave speed is capacity of it. It is often expressed in terms of non-dimensional, relative permittivity ε_r, where

$$\varepsilon_r = \varepsilon / \varepsilon_0$$

It is generally a complex, frequency-dependent quantity with real part representing storage and imaginary part representing loss of EM wave energy. For approximate calculation of GPR wave velocity, it is generally simplified to its real constant low frequency component. It is given as

Permittivity, real part: $\varepsilon'(w) = \varepsilon_\infty + (\varepsilon_s - \varepsilon_\infty) / (1 + w^2\tau^2)$

Permittivity, imaginary part: $\varepsilon''(w) = (\varepsilon_s - \varepsilon_\infty) + (w\tau) / (1+ w^2\tau^2)$

2.1.2 Conductivity - σ

It is essentially the capacity of a material medium to permit section of free electric charges through it affected by an electric field connected. Free charge transporters while moving through the medium under impact of connected electric field causes lessening and misfortune of vitality as hotness. On the off chance that conductivity worth is low, wave endures little measure of constriction while in exceptionally directing medium it is constricted by huge sum. So is the reason that GPR is incapable in exceptionally directing medium like saline conditions and high dirt substance. It is likewise intricate in nature and increments with the recurrence however acknowledged as little or immaterial for radar recurrence.

2.1.3 Permeability – μ

Practically the magnetic effect of materials like diamagnetic, paramagnetic phenomenon has insignificant effect on the propagating GPR wave velocity and hence their magnetic permeability is taken as μ_0.

2.2 Forward Modeling

2.2.1 Reflection Coefficient :-

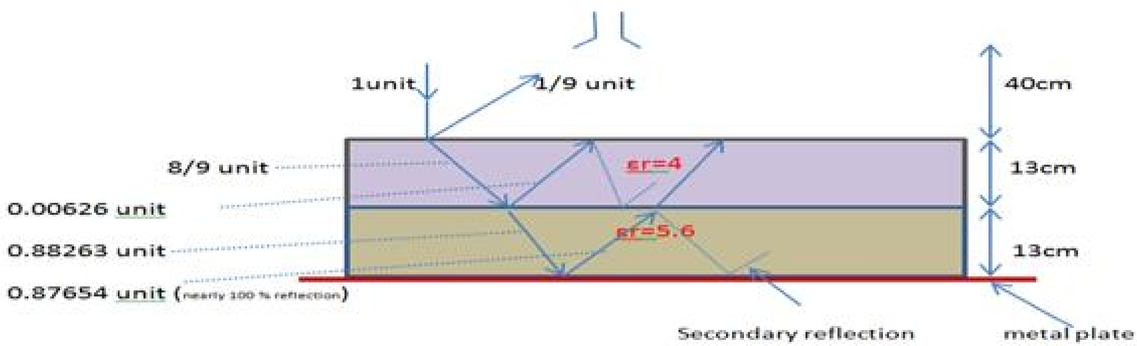

Figure 2.1.A two-layer ground subsurface with the transient response analysis

For single interface with normal incidence of wave, reflection coefficient is given as:

$$\Gamma = (\eta_2 - \eta_1) / (\eta_2 + \eta_1)$$

Where η is the wave impedance of corresponding medium and is given as

$$\eta = \sqrt{\mu/\varepsilon}$$

Since medium is considered as nonmagnetic in nature hence wave impedance is only function of medium relative permeability. Hence reflection coefficient for non-magnetic medium is given as:

$$\Gamma = (\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2})/(\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2})$$

Since **ε is a real number for GPR application**, so reflection coefficient at an interface of medium 1and 2 is represented by symbol r_{12} .

Transmission coefficient between non magnetic medium 1and 2 for normal incidence of EM wave are given as:

$$\tau_{12} = 2\varepsilon_1 / (\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2})$$

2.2.2 Global Reflection Coefficient :-

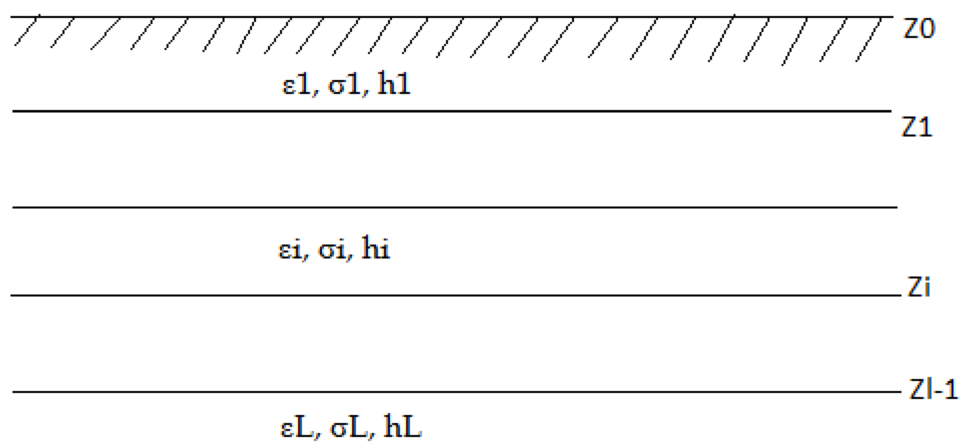

Figure 2.2. An L-layered ground subsurface with the corresponding electric and magnetic properties.

This expression can be generalized to find global reflection coefficient at i-th interface as:

$$\check{R}_{i,i+1} = \check{R}_{i,i+1} \prod^{i-1}_{k=0} (1 - \check{R}_{k,k+1}{}^2) \prod^{i}_{k=1} \exp(-2\alpha_k h_k)$$

Where,

$$\alpha = w \sqrt{(\mu\varepsilon)}/2 \, [\sqrt{(1+(\sigma/w\varepsilon)^2} - 1], \; \beta = w\sqrt{(\varepsilon\mu)}/2 \, [\sqrt{(1+(\sigma/w\varepsilon)^2} - 1]$$

Where α is attenuation constant in terms of Neper/meter, β is phase constant in terms of radian/meter.

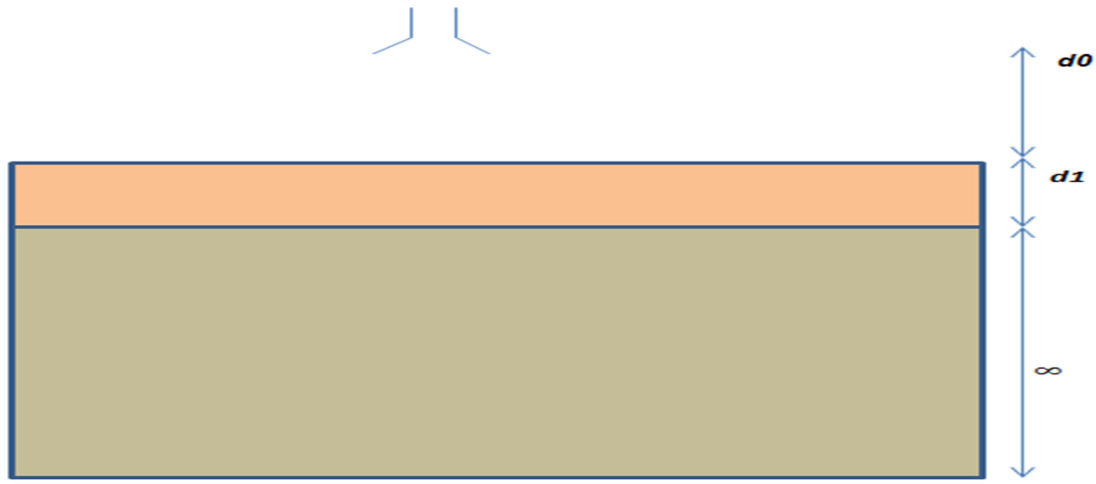

Figure 2.3. A simple mono media ground surface.

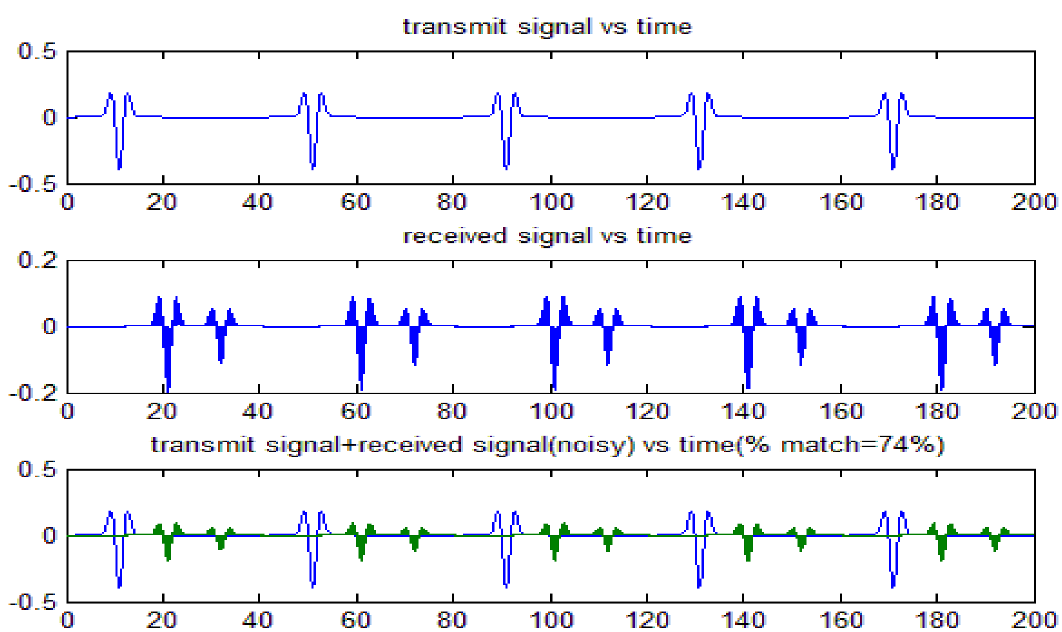

Figure 2.4. The MATLAB plot for the transmit and the received signal from a ground surface.

2.3 Synthetic Modeling of GPR system

A synthetic modelling of three layered medium consisting of air, soil and a general medium is done using the method proposed by Huang Zhonglai . The layered medium can be represented as:

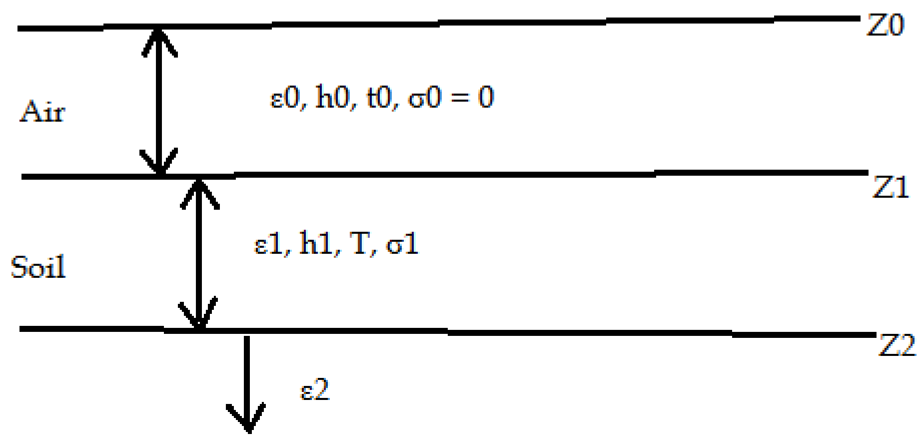

Figure 2.5. A three-layered media with different electric and magnetic properties.

Where $\check{r}_1$ is the global reflection coefficient due to first interface and is equal to local reflection coefficient at the interface of medium 1 and 2, since wave is not attenuated while travelling through air. Hence

$$\check{r}_1 = r_{12} = (\sqrt{\varepsilon_0} - \sqrt{\varepsilon_1})/(\sqrt{\varepsilon_0} + \sqrt{\varepsilon_1})$$

$\check{r}_2$ is the global reflection coefficient at the second interface and is given as:

$$\check{r}_2 = r_{23}\,(1 - r_{12}^2)\,\exp(-2\alpha_2 h_2)$$

Where r_{23} is the local reflection coefficient at the interface between 2nd and 3rd medium i.e. soil and an infinite medium and is given as:

$$r_{23} = (\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2})/(\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2})$$

Hence net reflection coefficient measured at the observation plane is superposition of that obtained from first and second interface, each delayed by respective time delay path. It can be given mathematically as:

$$\tilde{\rho}(t) = \check{r}_1\delta(t - t_0) + \check{r}_2\delta(t - t_0 - T)$$

Net Global Reflection Coefficient in frequency domain can be obtained by taking Fourier transform of equation (3.1) and it is given as:

$$\rho(f) = \tilde{\rho}(f)\exp\left[-i2\pi f\, (t_0 + T/2) \right]$$

Reflection Coefficient amplitude and Phase Spectrum was simulated for the three layered subsurface medium modelled as shown below.

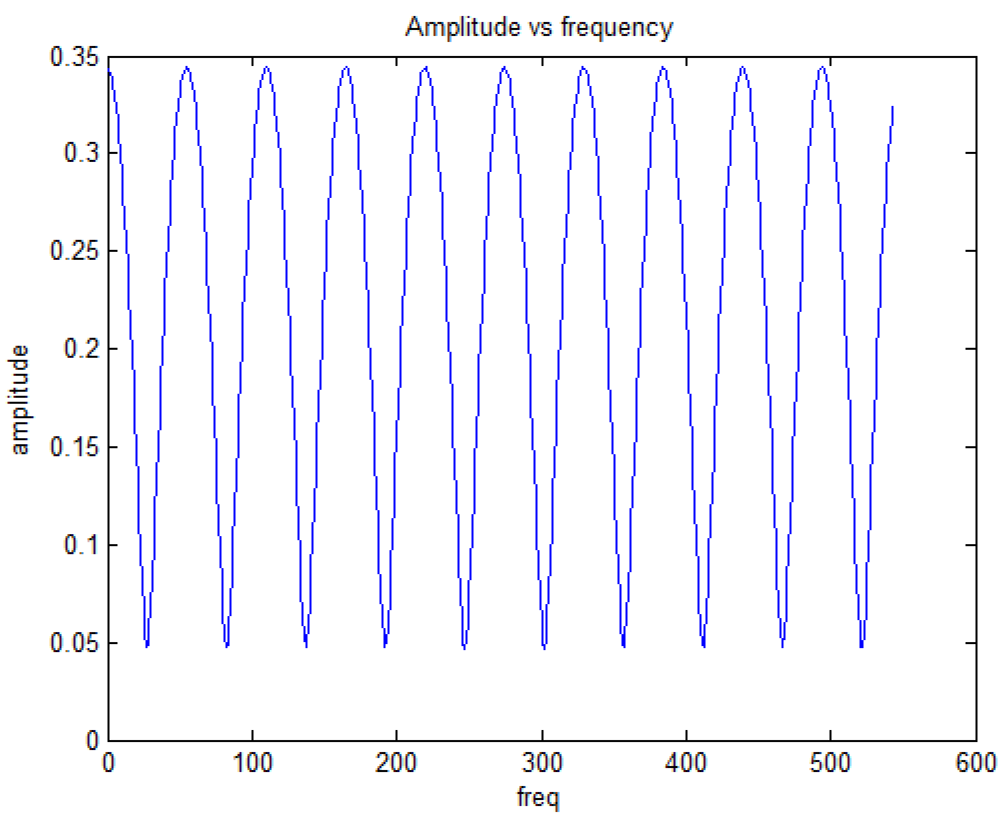

Figure 2.6. Modelled reflection coefficient amplitude spectrum.

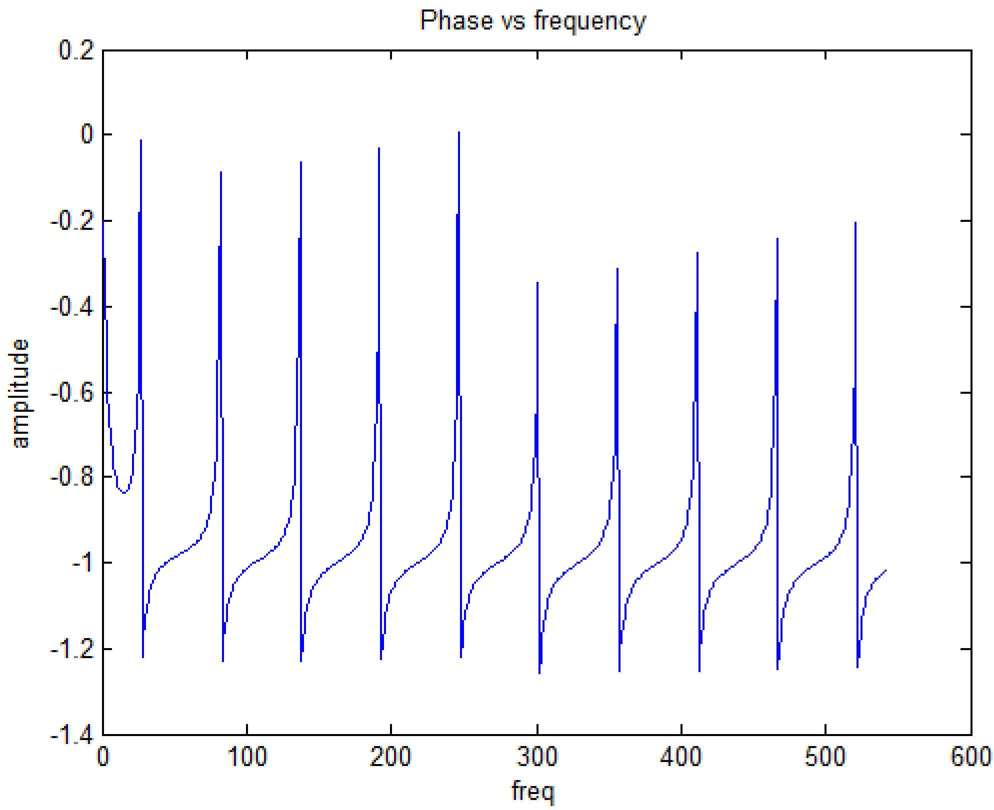

Figure 2.7. Modelled reflection coefficient Phase Spectrum.

2.4 Non-linear Optimization Techniques used in study of GPR:

- ❖ **Newton Raphson's Method**

$$p_{n+1} = p_n - f(p_n)/f'(p_n)$$

- ❖ **Conjugate Gradient Method**
- ❖ **Simplex Method**
- ❖ **Steepest Descent Method**
- ❖ **Nelder-Mead Method**

2.4.1 Steepest Descent Method:-

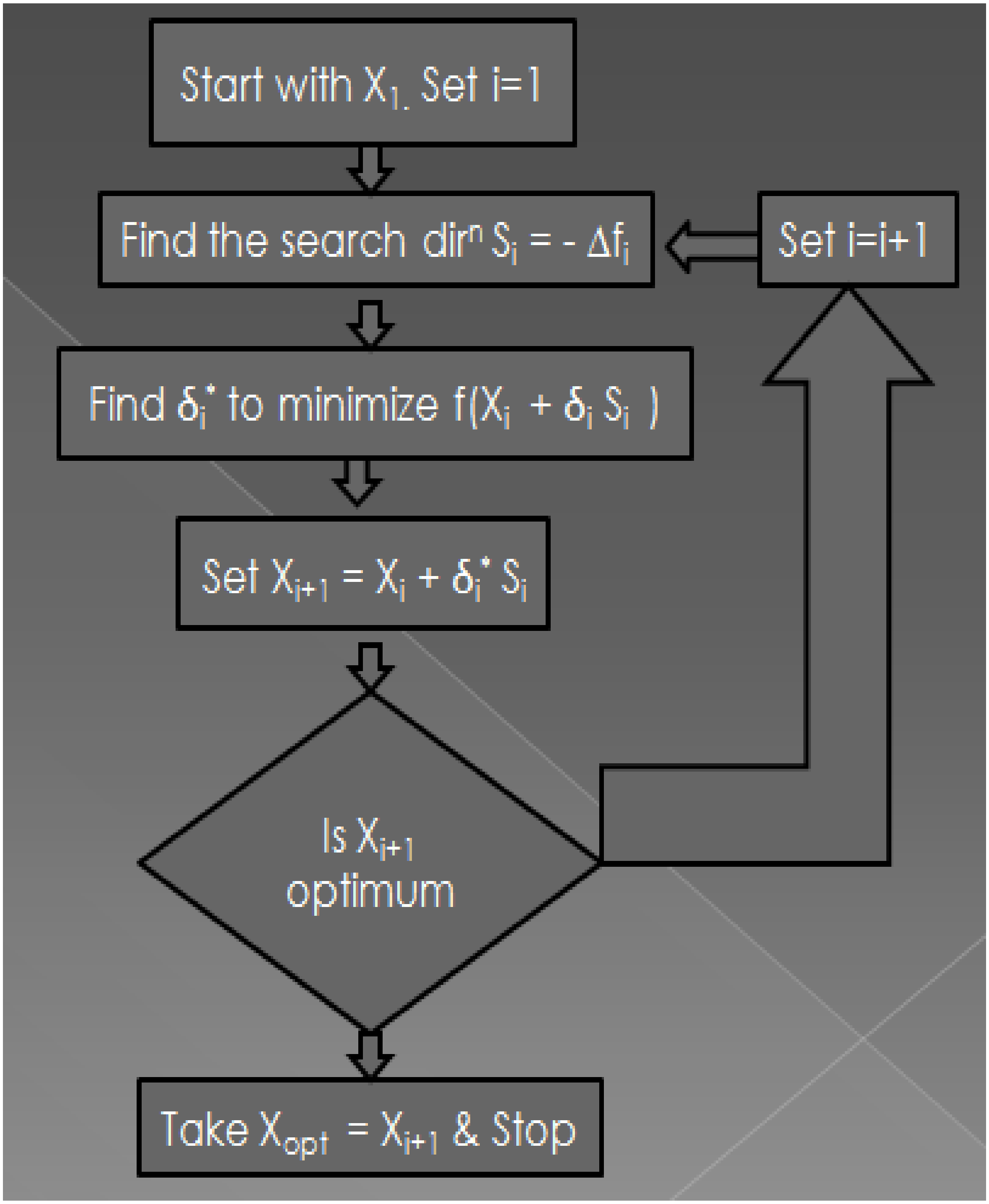

Figure 2.8. Algorithm for the Steepest Descent Method.

2.4.2 Conjugate Gradient Method:

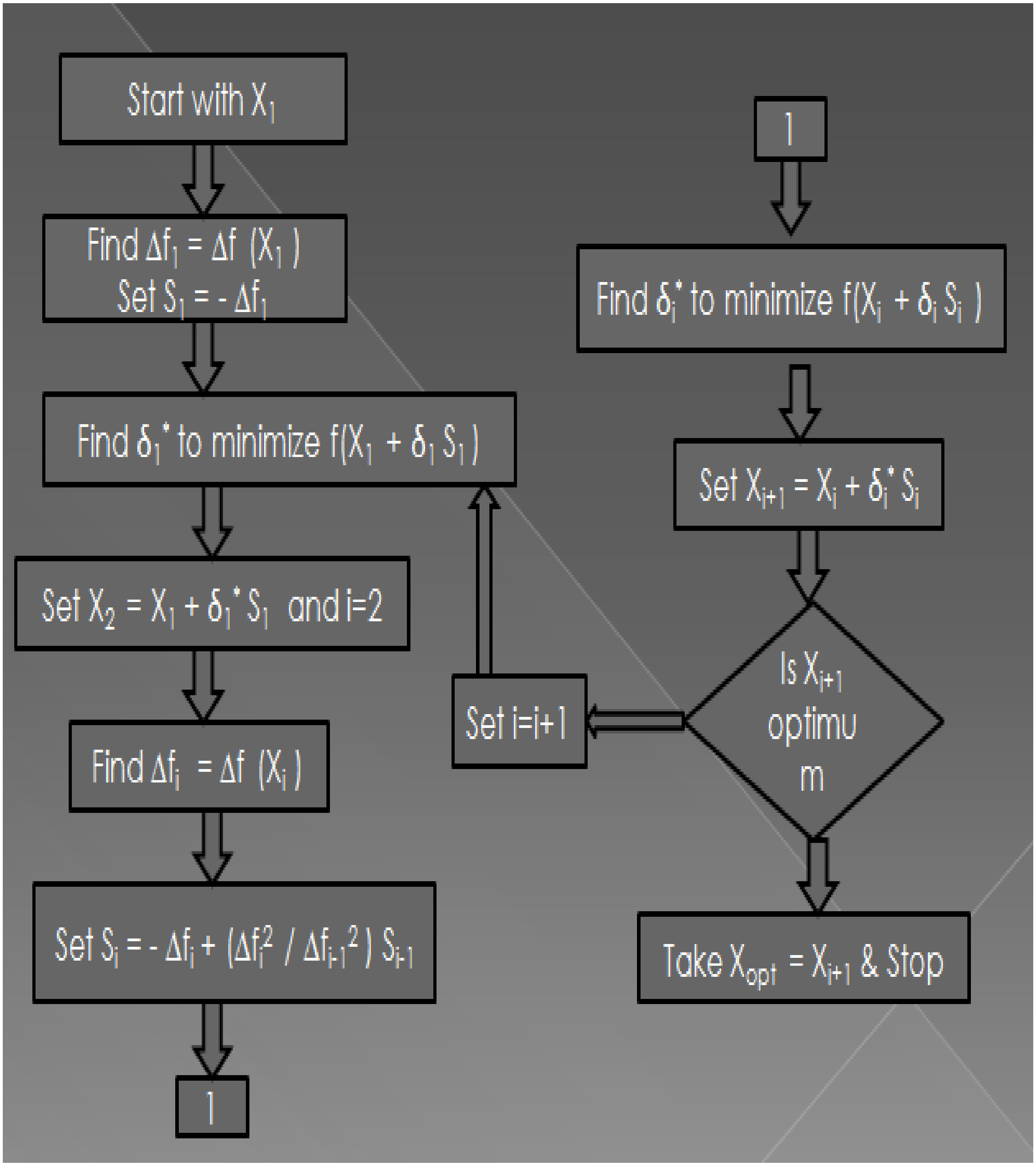

Figure 2.9. Algorithm for the Conjugate Gradient Method.

2.4.3 Minimization using Simplex method

$f(x_1 , x_2)= x_1 – x_2 + 2 x_1^2 + 2 x_1 x_2 + x_2^2$

starting from point x_1 = (0,0)

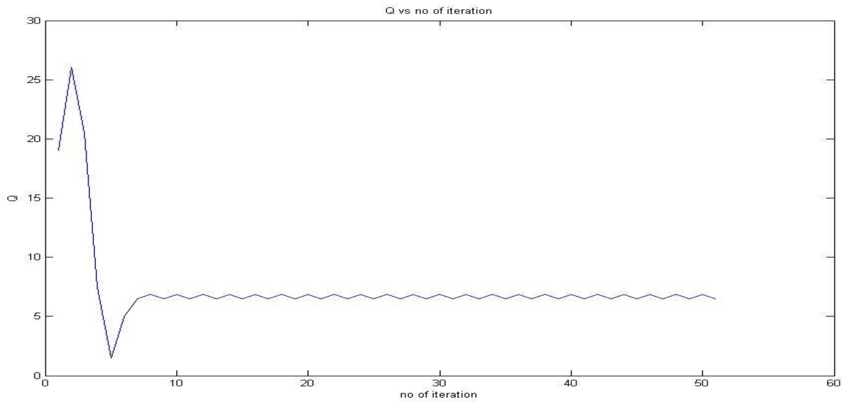

Figure 2.10. Plot for the function $f(x_1,x_2)$ using Simplex Method.

2.4.4 Minimization using Steepest Descent method

$f(x_1 , x_2)= x_1 – x_2 + 2 x_1^2 + 2 x_1 x_2 + x_2^2$

starting from point x_1 = (0,0)

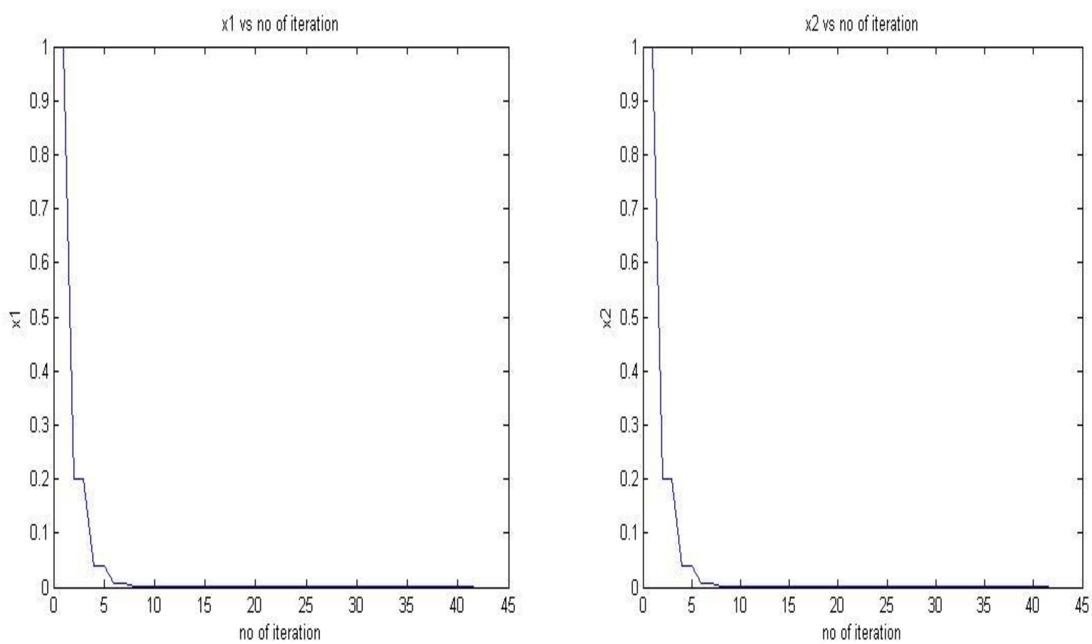

Figure 2.11. Plot for the function $f(x_1,x_2)$ using Steepest Descent Method.

2.5 Objective Function of the GPR modeling system

Let *w(f)* and *s(f)* be the frequency spectrum of radar emission wave and measured reflection wave respectively, the actual spectrum of reflection coefficient pair is given by :-

$$\rho_r(f) = s(f) / w(f)$$

The Objective function is given by :-

$$
\begin{aligned}
O_b(\varepsilon, \sigma, t_0, T) = \textstyle\sum_{f=fL}^{fH} \{abs[\ Re(s(f) / w(f)) \\
-2r_e\cos(\pi fT)\cos(\pi f(2t_0 + T)) \\
-2r_o\sin(\pi fT)\sin(\pi f(2t_0 + T)) \\
+ abs[\ Im(s(f) / w(f)) \\
-(-2r_e)\cos(\pi fT)\sin(\pi f(2t_0 + T)) \\
+2r_o\sin(\pi fT)\cos(\pi f(2t_0 + T))
\end{aligned}
$$

3. *Chapter 3*
Applications and Challenges

3.1 GPR Applications

With the advance in GPR technology and simultaneous improvement in its computing system due to fast processing computers, it is employed in various fields like:

i) Mining and Tunneling

GPR can detect changes in rock types and find application in defining geological structure, mine site evaluation, tunnelling design, mineral exploration etc.

ii) Forensics and Archaelogy

GPR can be used to uncover buried caches drugs, money, weapons as well as to locate unmarked graves. Since GPR can detect water content of subsurface hence can be used to map historical sites, to define road and building locations.

iii) Locating Pipes and Cables

Since GPR is having capability to detect metallic as well as non-metallic structures, it can be used to locate buried pipes and cables.

iv) Military and Security

Due to unique property of GPR to detect metallic as well as non-metallic structures, it can be used in search and rescue tunnel location, landmine detection etc.

v) Agriculture and Forestry

Due to GPR's sensitivity to water content and change in material composition, it can be used in monitoring soil moisture content, mapping of drainage and irrigation, to monitor health of living tree.

vi) Ice and Snow

GPR can be used for snow depth monitoring for ski slope management, ice thickness for winter road safety, location of avalanche victims and for glaciological and polar ice-cap research.

3.1.1 Advantages of GPR System:

i) Fast data acquisition capability.

ii) High resolution system.

iii) Works well for metallic as well as non-metallic target environment.

3.1.2. Drawbacks:

i) Complex nature of data received.

ii) Gives hyperbolic image of the target.

iii) Data interpretation is an erroneous and difficult task and needs expertise and deep understanding of the knowledge in the field.

3.2 Technical Challenges in GPR

GPR frameworks are like routine radar frameworks as in both measure target range i.e. spiral separation of the focus from the framework regardless of the bearing by deciding the two way travel time of an electromagnetic wave. Basically, however GPR frameworks are more confounded than expected (standard) radar frameworks because of some novel issues connected with transmitting and accepting Electromagnetic vitality through a subsurface medium. The main technical challenges in design and application of a Ground Penetrating Radar are:

i) Subsurface medium i.e. earth is typically inhomogeneous.

Inhomogeneous means the medium properties like, degree of media differs from point to indicate due differing arrangement like sand, water, air and other mineral stores of underground media. Subsequently the speed of an EM wave which is capacity of the medium properties likewise changes significantly from point to point and is obscure at first because of obscure medium. Subsequently the complete investigation of obscure subsurface and henceforth catching the target is a period expending and thorough methodology. In common radar framework travelling media is for the most part air through which the speed of propagation of an electromagnetic wave is known. Consequently target extent might be effortlessly figured by deciding two way travel time of the electromagnetic energy.

ii) Poor wave penetration in the subsurface medium

Some ground media like wet earth, salt water is great spongy of EM wave at the recurrence band of operation of GPR. Subsequently entrance through the subsurface is exceptionally poor and is not comparable to in air medium.

The wave gets constricted while spreading through a medium because of the medium properties called conductivity and weakening and thus infiltration is specifically relative to the recurrence of voyaging EM wave .Hence low recurrence yields more amazing subsurface entrance. Lamentably, lower recurrence brings about diminished target range determination which depends in converse way on the framework data transfer capacity i.e. recurrence of operation. So GPR framework needs to be legitimately intended to secure an exchange off between the two components relying on the provision.

iii) Clutters, noise, interferences etc are also involved in subsurface parameter identification using GPR.

4. Chapter 4
Summary and Conclusion

Summary and Conclusion

GPR is getting expanded examination center because of its mushrooming requisitions territory. At first time area provisions was more focussed in papers yet with some ruling preferences of recurrence space GPR on now is the ideal time area partner, SFCW GPR are late region of enthusiasm for the vast majority of the specialists.

Frequency domain application requires forward demonstrating of the framework. Numerous demonstrating plans are distributed by the GPR analysts having its own particular preferences and weaknesses. Some of them are provision particular i.e. gives more correct parameters estimation as contrasted with other demonstrating routines. In view of the dissection of spread of EM wave an explanatory demonstrating plan utilizing straightforward reflection coefficient based methodology is examined in this proposal. A manufactured model is embraced for subsurface multilayered medium and its parameters are evaluated utilizing example seek calculation with some former data of two way travel time of EM wave in soil layer medium. The effects evaluated are discovered to be faultless and guaranteeing.

The synthetic model is to be applied to the real time data set for testing of its validation. If it works so well in real time scenario, it can be employed for field application like landmine detection, water content estimation of thin soil layer.

- Selection of the transmitter power and operating frequency are the key factors in GPR design.
- Surface reflectivity and soil attenuation losses highly increase for after 1 GHz, especially for wet soils
- Nevertheless, higher frequencies are needed to obtain for better range/layer resolution and radar echo.
- So, lower frequency bands are used for deeper analysis, higher frequency bands are used for detection of smaller sub-surface objects or thinner layers located at shallow.

REFERENCES

[1] Huang zhonglai, Zhang jianzhong, *"Multi-Parameter Spectral Inversion for GPR Signals of Subsurface Layered Media"*, 14th International Conference on GPR, China, 2012.

[2] S. S. Rao, "OPTIMIZATION-Theory and Application".

[3] Jeffrey J. Daniels, Department of Geological Sciences, The Ohio State University Prepared as an appendix to a report to the U.S.EPA, Region V, Nov 25,2000.